IN THE CLAIMS

1. (Original) A method for positioning of an audio signal comprising steps of:
selecting a set of spatial functions, each having an associated scaling factor;
providing a first set of amplifiers and a second set of amplifiers, the gains of the amplifiers being a function of the scaling factors;
receiving a first audio signal;
providing a direction representing the direction of the source of the first audio signal;
adjusting the scaling factors depending on the direction;
applying the first set of amplifiers to the first audio signal to produce first encoded signals;
delaying the first audio signal to produce a delayed audio signal; and
applying the second set of amplifiers to the delayed audio signal to produce second encoded signals.

2. (Original) The method of claim 1 wherein the spatial functions are spherical harmonic functions.

3. (Original) The method of claim 2 wherein the spherical harmonic functions include at least the first-order harmonics.

4. (Original) The method of claim 1 wherein the spatial functions are discrete panning functions.

5. (Original) The method of claim 1 wherein for each of the first and second sets of amplifiers, the gain of each amplifier is based on the B-format encoding scheme.

6. (Original) The method of claim 1 further including:

providing a third set of amplifiers and a fourth set of amplifiers, the gains of the amplifiers being a function of the scaling factors;

receiving a second audio signal;

providing a direction representing the direction of the source of the second audio signal;

adjusting the scaling factors depending on the direction;

applying the third set of amplifiers to the second audio signal to produce third encoded signals;

delaying the second audio signal to produce a second delayed audio signal;

applying the fourth set of amplifiers to the second delayed audio signal to produce fourth encoded signals;

mixing the first and the third encoded signals, or the first and the fourth encoded signals; and

mixing the second and the fourth encoded signals, or the second and the third encoded signals.

7. (Original) The method of claim 6 wherein the second signal is a synthesized audio signal.

8. (Original) The method of claim 1 further including a decoding the encoded signals, the decoder comprising filters defined based on the spatial functions.

9. (Original) An audio recording apparatus for directionally encoding an audio signal comprising:

a source of an audio signal, the audio signal having a time-varying direction associated therewith;

a first set of multiplier circuits, each having a gain factor adaptable according to a direction for the audio signal, each having an input to receive the audio source, each having an output;

a delay element having an input coupled to the audio source and having an output; and

a second set of multiplier circuits, each having a gain factor adaptable according to a direction for the audio signal, each having an input to receive the output of the delay element, each having an output;

whereby the outputs of the first and second multiplier circuits comprise encoded audio signals.

10. (Original) The apparatus of claim 9 wherein the source includes a source of a synthesized audio signal.

11. (Original) The apparatus of claim 9 wherein the gain factors of the first and second multiplier circuits are based on spherical harmonic functions.

12. (Original) The apparatus of claim 11 wherein the spherical harmonic functions include at least zero- and first-order harmonics.

13. (Original) The apparatus of claim 9 wherein the gain factors of the first and second multiplier circuits are based on discrete panning functions.

14. (Original) The apparatus of claim 9 further including a data storage device having an interface effective for receiving and storing the outputs of the multiplier circuits.

15. (Original) A 3-dimensional audio recording system comprising:

a first soundfield microphone to produce first directionally encoded audio signals; and

a second soundfield microphone to produce second directionally encoded audio signals;

the first and second soundfield microphones are proximate each other at the positions of the ears of a notional listener;

wherein the first and second directionally encoded audio signals represent a 3-dimensional audio recording.

16. (Original) The system of claim15 further including a storage device for storing the first and second directionally encoded audio signals.

17. (Original) The system of claim 16 further including A/D circuitry for converting outputs of the microphones to digital signals, whereby the digital signals can be stored on the storage device.

18. (Original) The system of claim 15 wherein the first and second microphones are spaced apart by a distance substantially equal to the width of a human head.

19. (Original) The system of claim 15 wherein the first and second soundfield microphones are characterized by a set of spatial functions, the system further including a decoder for receiving the first and second directionally encoded signals to produce an audio signal, the decoder comprising filters defined based on the spatial functions.

20. (Original) A method of producing an audio signal from directionally encoded audio signals comprising steps of:

receiving directionally encoded audio signals according to a set of spatial functions;

generating a set of spectral functions based on the spatial functions;

providing a first set of decoding filters defined by left spectral functions; providing a second set of decoding filters defined by right spectral functions;

applying the first decoding filters to the encoded audio signals to produce a left-channel audio signal; and

applying the second decoding filters to the encoded audio signals to produce a right-channel audio signal.

21. (Original) The method of claim 20 wherein the set of spatial functions is defined by $\{g_i(\theta, \phi), i = 0, 1, \ldots N\text{-}1\}$ and the step of generating the spectral functions includes providing $L_i(f)$ and $R_i(f)$ such that $\Sigma_{\{i=0, \ldots N-1\}}\, g_i(\theta_p, \phi_p)\, L_i(f)$ approximates $\underline{L}(\theta_p, \phi_p, f)$ and $\Sigma_{\{i=0, \ldots N-1\}}\, g_i(\theta_p,$

ϕ_p) $R_i(f)$ approximates $\underline{R}(\theta_p, \phi_p, f)$, where $\underline{L}(\theta_p, \phi_p, f)$ is a set of left-ear HRTFs and $\underline{R}(\theta_p, \phi_p, f)$ is a set of right-ear HRTFs, where { θ_p, ϕ_p) $p = 1, 2, \ldots P$} is a set of directions and f is frequency.

22. (Original) The method of claim 21 wherein $\underline{L}(\theta_p, \phi_p, f)$ and $\underline{R}(\theta_p, \phi_p, f)$ are delay-free HRTFs.

23. (Original) The method of claim 21 wherein providing $L_i(f)$ includes solving, at each frequency f, the vector equation $\underline{L} \cong \boldsymbol{G}L$,, where:

the set of left-ear HRTFs $\underline{L}(\theta_p, \phi_p, f)$ define a Px1 vector $\underline{L}$,

$\boldsymbol{G}$ is a PxN matrix whose columns are Px1 vectors $G_{i,}$, $i = 0, 1, \ldots N-1$

each of the N spatial functions $g_i(\theta_p, \phi_p, f)$ defines the vector $G_{i,}$ and

the set of $L_i(f)$ defines the Nx1 vector L.

24. (Original) The method of claim 23 wherein providing $L_i(f)$ is obtained by $L = (\boldsymbol{G}^T\boldsymbol{G})$ $^1\boldsymbol{G}^T\underline{L}$.

25. (Original) The method of claim 24 wherein providing $L_i(f)$ includes projecting a Px1 vector $\underline{L}$ formed by the set of left-ear HRTFs $\underline{L}(\theta_p, \phi_p, f)$ over each of Px1 vectors G_i formed by the spatial functions $g_i(\theta_p, \phi_p)$ to compute the scalar product L_i.

26. (Original) The method according to claim 25 wherein an Nx1 vector L formed by the scalar products L_i is multiplied by the inverse of the Gram matrix $\boldsymbol{G}^T\boldsymbol{G}$.

27. (Original) The method of claim 23 wherein providing $L_i(f)$ is obtained by $L = (\boldsymbol{G}^T\boldsymbol{\Delta G})$ $^1\boldsymbol{G}^T\Delta\underline{L}$ where Δ is a diagonal PxP matrix where the P diagonal elements are weights applied to the individual directions (θ_p, ϕ_p), $p = 1, 2, \ldots P$.

28. (Original) The method of claim 20 where each weight is proportional to a solid angle associated with the corresponding direction.

29. (Original) The method of claim 28 wherein the spatial functions are spherical harmonic functions.

30. (Original) The method of claim 21 wherein the spherical harmonic functions include at least zero- and first-order harmonics.

31. (Original) The method of claim 20 wherein the spectral functions define filters $L_W(f)$, $L_X(f)$, $L_Y(f)$, and $L_Z(f)$ effective for decoding B-format encoded signals W_L, X_L, Y_L, Z_L W_R, X_R, Y_R, and Z_R, wherein the left-channel audio signal is defined by $W_L\, L_W(f) + X_L\, L_X(f) + Y_L L_Y(f) + Z_L\, L_Z(f)$and the right-channel audio signal is defined by $W_R\, L_W(f) + X_R L_X(f) - Y_R L_Y(f) + Z_R\, L_Z(f)$; whereby the left- and right-channel audio signals are suitable for playback with headphones.

32. (Original) The method of claim 20 wherein the spectral functions define filters $L_W(f)$, $L_X(f)$, $L_Y(f)$, and $L_Z(f)$ effective for decoding B-format encoded signals W_L, X_L, Y_L, Z_L W_R, X_R, Y_R, and Z_R; wherein the left-channel audio signal comprises two signals

a first signal $LF = 0.5\{[W_L + X_L][L_w(f) + L_X(f)] + Y_L L_Y(f) + Z_L L_Z(f)\}$ and

a second signal $LB = 0.5\{[W_L - X_L][L_W(f) - L_X(f)] + Y_L L_Y(f) + Z_L L_Z(f)\}$;

and wherein the right-channel audio signal comprises two signals

a first signal $RF = 0.5\{[W_R + X_R][L_W(f) + L_x(f)] + Y_R L_Y(f) + Z_R L_Z(f)\}$ and

a second signal $RB = 0.5\{[W_R - X_R][L_W(f) - L_X(f)] - Y_R L_Y(f) + Z_R L_Z(f)\}$;

whereby the left- and right- channel audio signals are suitable for playback over a pair of front speakers and a pair of rear speakers.

33. (Original) The method of claim 32 further including:

performing a first cross-talk cancellation on the *LF* and *RF* signals to feed the front speakers; and

performing a second cross-talk cancellation on the *LB* and *RB* signals to feed the rear speakers.

34. (Original) The method of claim 20 wherein the spatial functions are discrete panning functions having a direction, called a principal direction, where the spatial function is maximum and wherein all other spatial functions are zero.

35. (Original) The method of claim 34 wherein the spectral function associated with each spatial function is the delay-free HRTF for the corresponding principal direction.

36. (Original) The method according to claims 34 or 35 wherein one or more of the spatial functions have their principal direction corresponding to the direction of one of the loudspeakers.

37. (Original) The method according to claims 33 or 36 including performing cross-talk cancellation of the left and right audio signals before feeding the loudspeakers.

38. (Original) The method of claims 34 or 35 further including:

producing left-front and left-back signals based on the left-channel audio signal;

producing right-front and right-back signals based on the right-channel audio signal; and

combining the left-front, left-back, right-front, and right-back signals to produce outputs suitable for playback with a pair of front speakers and a pair of rear speakers.

39. (Original) The method of claim 38 further including:

performing a first cross-talk cancellation on the left-front and right-front signals to feed the front speakers; and

performing a second cross-talk cancellation on the left-back and right-back signals to feed the rear speakers.

40. (Original) The method of claim 39 wherein one or more of the spatial functions have their principal direction corresponding to the direction of the loudspeakers.

41. (Original) A method for reproducing an audio scene comprising:

selecting set of spatial functions;

producing directionally encoded audio signals including receiving a first audio source and applying the spatial functions to the first audio source to produce first encoded signals; and

decoding the encoded audio signals, including generating spectral functions based on the first spatial functions and applying the spectral functions to the encoded audio signals.

42. (Original) The method of claim 41 further including delaying the first audio source to produce a delayed source, applying the spatial functions to the delayed source to produce second encoded signals, the first and second signals comprising directionally encoded audio signals.

43. (Original) The method of claim 41 wherein the step of producing directionally encoded audio signals further includes receiving a second audio source, applying the spatial functions to the second audio source to produce second encoded signals, and mixing the first and second encoded signals.

44. (Original) The method of claim 43 wherein the second audio source is a synthesized audio signal.

45. (Original) The method of claim 41 wherein the spatial functions are spherical harmonic functions.

46. (Original) The method of claims 45 wherein the spherical harmonic functions include at least zero- and first-order harmonics.

47. (Original) The method of claim 41 wherein the spatial functions are discrete panning functions.

48. (Original) The method of claim 41 wherein the step of applying the spectral functions to the directionally encoded audio signals includes providing a set of filters defined by the spectral functions and feeding the encoded audio signals into the filters to produce reconstructed audio signals.

49. (Original) The method of claim 41 further including performing a cross-talk cancellation operation on the reconstructed audio signals to produce output suitable for playback with speakers.